[redacted]

NASA TT F-8254

N65-22858

(ACCESSION NUMBER)

10

(PAGES)

(NASA CR OR TMX OR AD NUMBER)

(THRU)

1

(CODE)

13

(CATEGORY)

FACILITY FORM 602

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GPO PRICE $ ____________

OTS PRICE(S) $ ____________

Hard copy (HC) $1.00

Microfiche (MF) .50

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON JULY 1962

DRAFT TRANSLATION NASA TT F-8254

JUL 2 1962

ON THE ANNUAL COURSE OF FREQUENCY OF MAGNETIC STORM OCCURRENCE

(O godovom khode chstot poyavleniya magnitnykh byr')

Geomagnetizm i Aeronomiya,
Tom II, No. 2, 321—325
Izd-vo A. N.SSSR,
Moskva, 1962

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ABSTRACT

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Examined is the dependnce of amplitudes and phases of the the first harmonics of storm number annual variation upon storms' intensity and the 11-year cycle. The phase of the first harmonic is subject to a cyclical variations with an amplitude near 2π and parallel to Wolf numbers. Together with other facts, this is considered as a consequence of existence in the streams of trapped magnetic fields. The amplitude of the second harmonic of storm number annual variation rises to 40 — 50 percent of the mean-annual level when passing from moderate to major storms.

Author

COVER TO COVER TRANSLATION

It was found in works [1, 2] that the annual variation in the magnetic activity contains parts Γ'_1 and Γ''_1, of which one (Γ'_1) is symmetric, and the other (Γ''_1) — dyssymmetric relative to the geographic equator. Inasmuch as a magnetic storm is a worldwide phenomenon encompassing both hemispheres, the annual course of the frequency of $\Gamma_{\text{б}}$ storms must be free from the part Γ'. Consequently, when examining $\Gamma_{\text{б}}$, we have to do with the part Γ'' in the pure form.

Analysis of $\Gamma_{\text{б}}$ is brought below according to data of the Irkutsk catalogue of storms covering the periods 1908 — 1918, 1925 — 1959, and includes the description of 820 storms, from moderate to very heavy.

The materials of the catalogue are used below to corroborate the reality of the part Γ'_1, the study of its structure and year-to-year variations.

1. The standard analytical representation of geomagnetic activity consists in Fourier series. However, in the case of this method is not always practical. Thus, for instance, one may expect that the harmonics' Γ_6 parameters obtained from the data of separate years may fluctuate amply, inasmuch as the mean frequency of storms for a year does not exceed 20, i. e. the statistical volume is small. That is why instead of parameters of harmonics Γ_6 by the data of each year, we utilized for the study of Γ_6 variations in the 11-year cycle Table 1 (next page), where the values Δ – winter-summer differences of storm frequency for each year (winter from November to February, summer from May to August). It is easy to be convinced that

$$\int_{1.\mathrm{V}}^{30.\mathrm{VIII}} \cos(n\tau - \psi_n)\, d\tau \equiv \int_{1.\mathrm{XI}}^{28.\mathrm{II}} \cos(n\tau - \psi_n)\, d\tau^1, \quad n = 2, 4, 6\,.$$

Besides,

$$\int_{1.\mathrm{V}}^{30.\mathrm{VIII}} \cos(n\tau - \psi_n)\, d\tau = \int_{1.\mathrm{XI}}^{28.\mathrm{II}} \cos(n\tau - \psi_n)\, d\tau = 0\,, \quad n = 3$$

(the limits' value is found from the conditions $\tau = 0°$ for 1 Jan., $\tau = 360°$ for 31 December). Hence it may be seen that the quantities Δ are characteristics of the first harmonic Γ_6. Consequently, in order to be assured of the reality of the first harmonic Γ_6 (designated below by Γ''_1), it is sufficient to find that the series of Δ values is not a series of random quantities. The series

$$\Delta_1, \Delta_2, \Delta_3, \ldots, \Delta_n\,,$$
$$\frac{1}{2}(\Delta_1 + \Delta_2)\,, \frac{1}{2}(\Delta_3 + \Delta_4)\,, \ldots, \frac{1}{2}(\Delta_{n-1} + \Delta_n)\,,$$
$$\frac{1}{3}(\Delta_1 + \Delta_2 + \Delta_3)\,, \frac{1}{3}(\Delta_4 + \Delta_5 + \Delta_6)\,, \ldots, \frac{1}{3}(\Delta_{n-2} + \Delta_{n-1} + \Delta_n)$$

were composed according to data of Table 1.

Subsequently, computed were the values of the "equivalent number of repetitions" [3]:

$$E(h) = \left[\frac{m(h)\sqrt{h}}{m(1)}\right]^2,$$

where h is the number of components in every term of the series, m — is the series' standard deviation.

T A B L E 1

Values of summer-winter differences in the frequency of various categories of storms

Year	All storms	Major st.	Moderate storms with grad. commencem.	BAYS	Year	All storms	Major storm	Moder. storms with G C	Bays
1908	3	0	—1		1937	0	—1	1	23
1909	1	1	0		1938	1	1	2	25
1910	—2	—1	—3		1939	—9	—4	—2	19
1911	1	0	—1		1940	5	0	3	22
1912	—2	0	—1		1941	2	—1	4	36
1913	1	0	0		1942	2	1	0	13
1914	—4	0	—2		1943	2	1	3	41
1915	3	0	2		1944	0	1	0	25
1916	—5	—1	—2		1945	6	1	4	24
1917	—8	—2	—2		1946	—5	—2	—2	6
1918	1	1	0		1947	—4	—5	3	18
1925	—3	0	—1		1948	2	—1	3	23
1926	3	1	1		1949	2	0	6	6
1927	—5	—1	—3		1950	—3	—2	—4	25
1928	—3	—2	1		1951	0	—2	3	
1929	—2	1	1		1952	3	—1	4	
1930	—8	—2	—6	31	1953	—4	1	—4	
1931	2	0	2	25	1954	3	0	3	
1932	0	—1	1	27	1955	—1	2	0	
1933	—1	0	—1	7	1956	1	1	1	
1934	—1	1	1	34	1957	—3	—1	2	
1935	0	0	0	20	1958	—12	—3	—5	
1936	—1	0	—1		1959	—2	—3	5	

The values E(h) which may be expected for a random serie of differences, is 1/h. These values and the computed values E(h) are brought out in Table 2. Here are compiled also the values E'(h) found upon exclusion of the secular course of quantities Δ; this was reached by substraction from Δ of slipping 11-year averages.

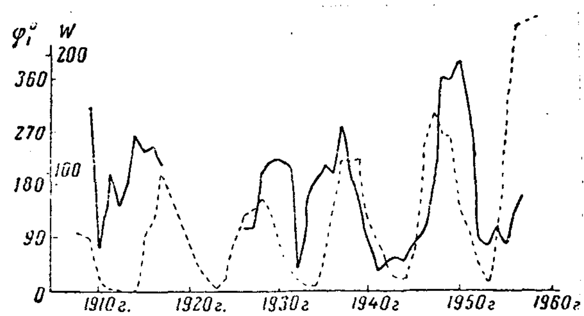
Data of Table 2 allow the conclusion that the series of Δ values is not random, i.e. the first harmonic Γ_6 does exist, and its year-to-year variations contain a regular element.

2. One may get convinced of the fact that the variations of the quantities Δ have an approximately 11-year periodicity, and are linked with the solar activity cyclicity. Indeed, the mean values Δ, computed only and separately for the maximum and minimum epochs:

Maximum epochs : 1916 - 1917, 1928-1929, 1938-1939, 1947-1948, 1957 - 1958.

Minimum epochs : 1912-1913, 1932-1934, 1942-1944, 1954 - 1955,

resulted respectively equal to -4.1 and $+0.16$, while the difference between these values is, according to Student criterion, reliable with a probablity > 0.995. Still more convincing are the results illustrated by the following graph, where secular phase variations of the first harmonic of the slipping three-year mean storm frequencies' course are plotted (solid line). For comparison presented here are also the Wolf numbers W (dotted line).



It is visible that phase variations of the annual wave take place smoothly, and that they repeat rather well the W variations.

The 11-year cyclicity * of parameter Γ_6 variations narrows considerably the circle of possible causes of Γ_σ formation [2]: The annual variations of ionosphere parameters and of the distance Earth — Sun cannot constitute those causes, but apparently, the yearly variations of the parameters of Earth's magnetic field and corpuscular stream interaction can. Because of their solar origin, the 11-year cyclicity is inherent of the latter.

TABLE 2

h	1	2	3	4	5	6	7	8	9	10	11
$E(h)$	1,00	0,77	1,10	0,66	0,98	0,59	0,88	0,58	0,52	0,60	0,67
$E'(h)$	1,00	0,93	0,19	0,41	0,52	0,16	0,20	0,21	0,13	0,12	0,47
$1/h$	1,00	0,50	0,33	0,25	0,20	0,18	0,14	0,12	0,11	0,10	0,09

3. It may be shown that the cyclical variations of the phase Γ_σ diminish or disappear completely at passing from the frequency of all storms to that of storms of distinct categories. Indeed (see Table 1), major storms have values $\Delta < 0$ at all phases of the cycle (aside from the minimum epoch, where Δ is near zero). In case of moderate storms with gradual commencement (G-storms) the values $\Delta > 0$ and $\Delta < 0$ are distributed with about the same frequency along all the phases of the cycle. Their mean values for the maximum and minimum epochs constitute -2.16 and 0.41, while the difference between those two values, estimated with the aid of the Student criterion resulted unreliable. In the following group of disturbances (bays) the values $\Delta > 0$ for all the 20 years are compiled in the Table.

The data brought forth show, that two types of Γ_6 exist : one with a maximum during the season November-February for the small disturbances (bays), and the other with a maximum during the May — August season, for major and very great SC — storms. Not everyone

* in the sense "cycle of operations"

of these Γ_6 types varies (or varies little) in the 11-year cycle. This is also seen from Table 3, where we compiled the amplitudes and the phases of the maximum of Γ_6 harmonics according to data of the Irkutsk catalogue (the amplitudes being related to the mean-annual level, and $\delta\varphi$ — the probable phase error). It may be seen from Table 3 that in case of large or very large storms, and also of moderate SC — storms, Γ_6 has a summer maximum, and the bays — a sharp winter maximum. The moderate G- storms constitute a transition group.

Thus, the explanation of the complex pattern of phase variation may be simplified and reduced to the description of two mechanisms that do not vary in the 11-year cycle. One of them acts also in case of weak G—storms, conditioning their winter maximum, the other — in case of major storms and all SC-storms, creating their summer maximum. The resulting wave obviously ~~changes~~ the phase in the 11-year cycle on account of the variation of the relative weight of these two of its components.

4. The referred-to mechanisms of Γ_6 formation are proposed in [2, 4], where the existence in the streams of frozen-in, radially directed from the Sun magnetic fields is assumed. The intensity of the fields is of the order of $10^{-5} - 10^{-6}$ gauss. The existence of such fields has been recently corroborated [5]. A radial field in interplanetary space has been also recently assumed by the authors of reference [6].

The direction of the field creating Γ_6 of strong and weak storms must obviously be opposite: in case of major storms the field must be directed from the Sun to the Earth, and in case of weak storms — from the Earth to the Sun. If we assume that the strong and the weak storms are respectively generated by the "spine" and the "edges" of the streams, we may reach a representation of a strear trapped field with lines of force stretched in opposite directions at the edges and in the "spine" of the stream.

TABLE 3

AMPLITUDES AND PHASES OF THE MAXIMUM OF HARMONICS Γ_6.

Magnetic storms	Number of storms	r_1	φ_1°	$\delta\varphi_1^\circ$	r_2	φ_2°	$\delta\varphi_2^\circ$	r_3	φ_3°	$\delta\varphi_3^\circ$	r_4	φ_4°	$\delta\varphi_4^\circ$
Moderate G-	427	0,13	78	31	0,16	203	13	0,08	172	50	0,03	324	46
Great G-	92	0,10	167	37	0,34	160	19	0,25	36	53	0,28	240	16
Moderate SC-	171	0,27	197	21	0,21	104	33	0,13	94	28	0,13	314	33
Great SC-	130	0,19	205	39	0,46	162	13	0,09	284	26	0,30	13	9
Bays	1441	0,70	347	—	0,23	175	—	0,08	148	—	0,11	308	—

5. Let us call our attention to some of the data of the above Table 3. We may assume. that the errors δr in the determination of quantities r (amplitudes of harmonics) from one group of storms to another according to the law $1/\sqrt{N_k} = \varepsilon$, where N_k is the number of storms. Assuming $\delta\varphi_K = \delta r_K / r_K$, it is easy to obtain

$$r_{\rm I}^*:r_{\rm II}^*:r_{\rm III}^*:r_{\rm IV}^* \approx \frac{\varepsilon_{\rm I}}{\delta\varphi_{\rm I}} : \frac{\varepsilon_{\rm II}}{\delta\varphi_{\rm II}} : \frac{\varepsilon_{\rm III}}{\delta\varphi_{\rm III}} : \frac{\varepsilon_{\rm IV}}{\delta\varphi_{\rm IV}} \qquad (1)$$

(below the indices I, ..., IV will be respectively referred to moderate and great G —storms, to moderate and great SC— storms). According to Table 3, we find with the help of (1) for the first harmonic

$$r_{\rm I}^* : r_{\rm II}^* : r_{\rm III}^* : r_{\rm IV}^* = 0{,}86 : 1{,}48 : 1{,}92 : 1{,}1$$

Hence, we may see that the amplitude r_1^* in the group of moderate G-storms, just as the value r_1 ($= 0.13$) are substantially smaller. than in the group of great and SC— storms. The phase of the first harmonic for that group of storms ($\varphi_1 = 78^\circ$) has an intermediate value (Table 3). This proves once more that the Γ_1'' class of moderate G—storms has an intermediate character, transitional between bays and major or SC— storm categories.

It is also interesting to note that the moderate SC— storms already have a Γ_6-type with a summer maximum and values r_1^*, r_1, which are the greatest amongst the four groups of storms, and not the transitional type Γ_6. According to point 5, this circumstance points to the fact that the radial magnetic field in the streams responsible for the SC-storms, is intensified by comparison with the G-storms (magnetic cushion) and is directed along the velocity vector. For the amplitudes of the second harmonic of Γ_σ the expression (1) gives the relation :

$$r_I^* : r_{II}^* : r_{III}^* : r_{IV}^* = 1{,}92 : 2{,}91 : 1{,}24 : 3{,}50,$$

that is close to the ratio if quantities r_2 in Table 3 :

$$r_I : r_{II} : r_{III} : r_{IV} = 0{,}16 : 0{,}34 : 0{,}21 : 0{,}46.$$

Consequently, both the ratio of r_2 and r^*_2 quantities show a significant increase in the amplitudes of the second harmonic of σ with the transition from moderate to great storms (more than twice). It is interesting to note, that SC-storms have greater values r_2 than G-storms in the group of moderate, and particularly in that of great storms. This points to the fact [1], that the equinoctial maxima of activity are not the consequence of only the effect, inasmuch as the angular width of the streams generating the (flaring) SC-storms, must be greater than in case of floculated G – storms [7, 8].

********** THE END **********

IZMIRAN

Paper entered on 26 Dec.1961

Translated by ANDRE L. BRICHANT
for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
July First, 1962

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